Incidence and Secondary Transmission of SARS-CoV-2 Infections in Schools

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abstract

BACKGROUND: In an effort to mitigate the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), North Carolina closed prekindergarten through grade 12 public schools to in-person instruction on March 14, 2020. On July 15, 2020, North Carolina's governor announced schools could open via remote learning or a hybrid model that combined in-person and remote instruction. In August 2020, 56 of 115 North Carolina school districts joined The ABC Science Collaborative (ABCs) to implement public health measures to prevent SARS-CoV-2 transmission and share lessons learned. We describe secondary transmission of SARS-CoV-2 within participating school districts during the first 9 weeks of in-person instruction in the 2020–2021 academic year.

METHODS: From August 15, 2020 to October 23, 2020, 11 of 56 school districts participating in ABCs were open for in-person instruction for all 9 weeks of the first quarter and agreed to track incidence and secondary transmission of SARS-CoV-2. Local health department staff adjudicated secondary transmission. Superintendents met weekly with ABCs faculty to share lessons learned and develop prevention methods.

RESULTS: Over 9 weeks, 11 participating school districts had >90 000 students and staff attend school in person. Among these students and staff, 773 community-acquired SARS-CoV-2 infections were documented by molecular testing. Through contact tracing, health department staff determined an additional 32 infections were acquired within schools. No instances of child-to-adult transmission of SARS-CoV-2 were reported within schools.

CONCLUSIONS: In the first 9 weeks of in-person instruction in North Carolina schools, we found extremely limited within-school secondary transmission of SARS-CoV-2, as determined by contact tracing.

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Drs Zimmerman and Benjamin conceptualized and designed the study, designed the data collection instruments, coordinated and supervised data collection, collected data, conducted the initial analyses, drafted the initial manuscript, reviewed and revised the manuscript, and critically reviewed the manuscript for important intellectual content; Drs Brookhart and Zadrozny designed the data collection instruments, collected data, conducted the initial analyses, and reviewed and revised the manuscript; Drs Akinboyo, Boutzoukas, McGann, Maradiaga Panayotti, Smith, Armstrong, and Weber reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: https://doi.org/10.1542/peds.2020-048090

Accepted for publication Jan 5, 2021

WHAT'S KNOWN ON THIS SUBJECT: Many school districts across the United States are deciding whether to reopen for in-person learning for the second semester. The frequency of within-school transmission of severe acute respiratory syndrome coronavirus 2 in communities with widespread transmission is unknown.

WHAT THIS STUDY ADDS: During the first 9 weeks of in-person instruction in 11 school districts with nearly 100 000 students and staff, secondary transmission of severe acute respiratory syndrome coronavirus 2 infections was extremely rare.

To cite: Zimmerman KO, Akinboyo IC, Brookhart MA, et al. Incidence and Secondary Transmission of SARS-CoV-2 Infections in Schools. *Pediatrics.* 2021;147(4):e2020048090

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes the illness coronavirus disease 2019 (COVID-19) and is responsible for the pandemic that has affected >12 million Americans.[1,2] In the United States, prekindergarten through grade 12 (K–12) public schools are composed of >50 000 000 children and 5 000 000 adults, many of whom have risk factors for severe COVID-19. In the first weeks of the pandemic, most US schools preemptively closed to in-person instruction through the end of the 2019–2020 school year to prevent transmission of SARS-CoV-2. Public schools that educate K–12 serve a central role in US education, public health, and the economy. Therefore, closing public schools has substantial repercussions for children and families.

On July 15, 2020, the governor of North Carolina allowed school districts to decide whether to provide all remote learning or some in-person instruction via a hybrid model, through which all students may attend school in person[3] but daily operations occur at less than full capacity. Families in districts offering the hybrid model could choose between hybrid or all remote learning. For many schools, the hybrid model resulted in students attending in-person school for 2 days each week (eg, 50% of children receive in-person instruction Monday and Tuesday; 50%, Thursday and Friday; and Wednesday is used for cleaning the building during remote instruction for all students). Districts that chose the hybrid model were also required to follow pandemic mitigation strategies, as directed by the North Carolina Department of Health and Human Services (NCDHHS) Strong Schools tool kit.[4] In particular, districts were required to have universal mask wearing for all individuals ≥5 years of age (except the adapted curriculum, during meals, and when sufficiently distanced outside), implement 6-foot distancing, and wash hands (wear a mask, wait 6 feet apart, wash hands ["3W's"]) as well as perform daily symptom monitoring and temperature checks. Additional details on implementing mitigation strategies were left to the discretion of each school system.

Local school district leaders approached faculty from Duke University and the University of North Carolina at Chapel Hill, seeking to better understand the scientific underpinnings of SARS-CoV-2 mitigation strategies and to further guide district-specific policies around reopening. In response to this request, faculty at Duke University and the University of North Carolina at Chapel Hill developed The ABC Science Collaborative (ABCs).[5]

In this article, we describe ABCs and evaluate our hypothesis that in-person instruction, if accompanied by assiduous adherence to masking, distancing, and hand hygiene, would not result in substantial risk of SARS-CoV-2 spread within schools for children or staff. We also report on lessons learned from efforts to provide safe in-person public education to students across North Carolina during this pandemic.

METHODS

Formation and Work of ABCs

After initial requests and interest from local school districts, faculty and staff developed a program with 3 aims: (1) educate school leaders, staff, and the community; (2) have school-specific data drive decision-making; and (3) generate new science to improve health-related outcomes for children. Faculty then offered the program to the remaining school districts in North Carolina. As the first quarter of instruction progressed, participating school districts agreed to a memorandum of understanding to share lessons learned. Districts had the option to withdraw from the collaborative at any time, and the degree of participation in activities was left to the discretion of each district. Similarly, data sharing across ABCs was encouraged but not compulsory.

District Education Plan and Professional Learning Community

ABCs developed a multifaceted educational plan targeted at adult stakeholders. In the 3 weeks before the start of the school year and throughout the first 9 weeks of instruction, ABCs provided 60-minute educational webinars and question and answer sessions focused on the prevention, transmission, and outcomes of SARS-CoV-2 infection to superintendents, teachers, local school leaders, staff, parents, and school boards. Additionally, ABCs faculty moderated weekly small group sessions with superintendents and school leaders to share emerging science and discuss implementation plans for COVID-19 school policies.[6]

Peer-to-Peer Support for Public Health Prevention Measures

Over 9 weeks of instruction, superintendents and ABCs faculty met weekly to address questions related to policy, revise district policies on the basis of lessons learned, and draft common documents related to SARS-CoV-2 prevention in schools. Specifically, the superintendents from districts conducting in-person instruction shared information and protocols around reopening (and staying open). ABCs faculty and staff provided scientific input on mitigation strategies. Resulting documents, including a key document outlining 12 principles, were made available to all members of the collaborative (Supplemental Fig 3). Districts participating in ABCs adopted varying degrees of the 12 principles, although midway through the 9 weeks of instruction, most had implemented at least 10 of the 12 principles as a result of lessons learned.

Evaluation of Secondary Transmission

Study Population

During the first 9 weeks of instruction in North Carolina public schools, participating school districts provided confidential data to ABCs about SARS-CoV-2 cases and secondary transmission in schools. We specifically requested data from districts that had implemented the hybrid model for the entire 9-week period and had tracked cases and secondary transmission by school.

Outcome Measures

The primary outcome was the number of within-school (secondary) transmissions of SARS-CoV-2 in traditional public schools conducting in-person learning. Case adjudication of within-school transmission was performed via contact tracing by the local health department. All close contacts were quarantined for 14 days; testing for contacts was encouraged by the NCDHHS but not required. Secondary outcomes included clusters, defined by the NCDHHS as a minimum of 5 cases in the same facility within a 14-day period and plausible epidemiological linkage between cases[7]; consequently, clusters do not capture all cases of within-school transmission.

Data Sources

For districts participating in data sharing, we obtained publicly available data for the number of staff, student enrollment, and student distribution by race, ethnicity, and expenditure for the 2019–2020 academic year. We confirmed the number of children attending in person with each superintendent. Data on timing and instructional models for each district were obtained via combinations of the following: conversations with school superintendents through the Lighting Our Way Forward[8] collaborative program to guide school reopening between the NCDHHS, the North Carolina State Board of Education, and the Department of Public Instruction; data on EdNC.org; and policy updates from district Web sites.[9] Data for clusters and community transmission across the state were available on the NCDHHS Web site.[10] After local health department adjudication, superintendents reported data on primary and secondary cases by school and week of instruction to ABCs faculty. Only those 11 school districts that provided in-person instruction for 9 weeks and were able to report both primary and secondary infections were included in the analysis of secondary transmission.

Definitions

There are 100 counties in the state of North Carolina, each of which has a school district (n = 100 county districts). Additionally, some cities within these counties have their own school districts separate from the county schools (n = 15 city districts). Widespread community transmission was defined as molecular test results positive in $>$1 of 1000 county residents over 14 days for $\geq$5 of the 9 instructional weeks.

Analyses

We performed descriptive analyses to aggregate data from contributing districts to characterize the number of people in school buildings, secondary transmission in schools, and transmission within surrounding communities.

Institutional Review Board Approval

No personal health information data were obtained or transmitted; this work is part of the ABCs research program (Duke University Institutional Review Board Pro00107036).

RESULTS

Study Cohort

Of 115 school districts in North Carolina, 56 participated in ABCs (Fig 1, Table 1). Districts participating in ABCs tended to be larger in population (7739 vs 4516), had fewer non-Hispanic white students (46.8% vs 54.9%; Table 1), and offered fewer weeks of in-person instruction (3.6 of 9 weeks vs 5.7 of 9 weeks).

Of participating ABCs school districts, 35 of 56 offered in-person instruction for at least part of the 9 weeks and 21 remained all remote. Of the 35 school districts offering in-person instruction, 17 offered it for all 9 weeks and 18 offered it for part of the 9 weeks; of these 18, approximately half (8 of 18) offered in-person instruction for $\geq$4 weeks. None of the participating school districts had to close during the 9 weeks because of SARS-CoV-2 transmission. Eleven of the 17 school districts that offered in-person instruction for all 9 weeks participated in this study, of which 9 were county districts and 2 were city districts. These districts provided primary infections by school and week of instruction (Table 2). These districts further provided all cases of secondary transmission by school and week of instruction, as determined by local public health contact tracing.

Across North Carolina, the rate of SARS-CoV-2 infections was 1–2 cases per 1000 residents per week for most of the 9 weeks examined (Fig 2). The rate of community-acquired cases was slightly higher in the 11 counties that house the 11 school districts contributing data for this report. Figure 2 reveals the number of community-acquired cases within the 11 school districts per 1000 students.

Primary Cases and Secondary Transmission

Across the 11 school districts, 773 community-acquired SARS-CoV-2 infections were documented by molecular testing; however, there

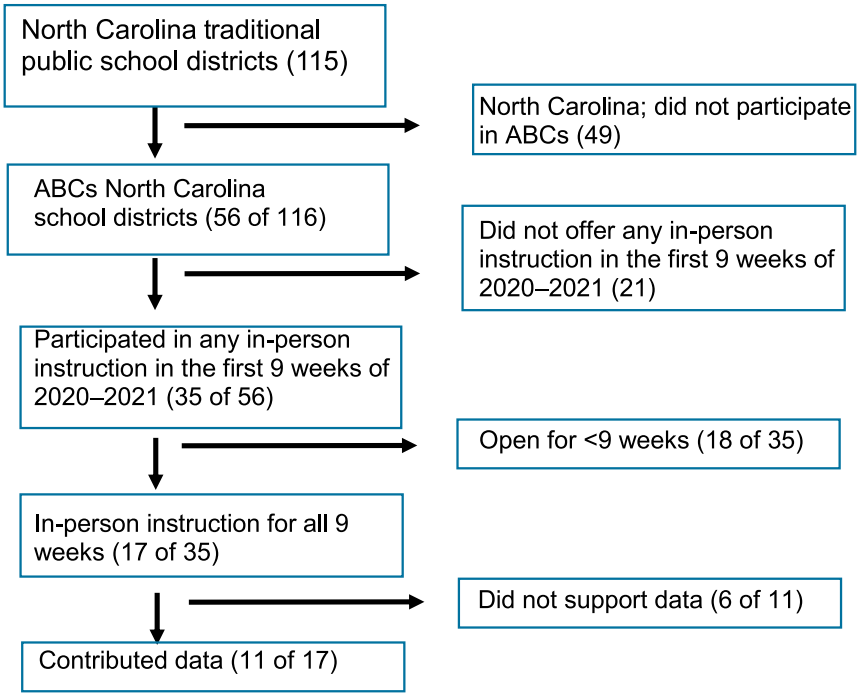

FIGURE 1
Formation of the districts: formation of the cohort of districts that shared data.

were only 32 adjudicated cases of secondary transmission across the 11 districts combined in 9 weeks of instruction. Six districts had 0 secondary infections, 2 had 1 case, and 3 had multiple cases. There were 6 cases of secondary transmission in the prekindergarten setting, 11 in elementary schools, 6 in middle schools, 5 in high schools, and 4 in K–12 schools. There were no cases of child-to-adult within-school transmission.

Clusters of SARS-CoV-2 Infection

During the first 9 weeks of instruction across the state of North Carolina, there were 38 reported clusters in schoolchildren; of these, 2 occurred in charter schools (10 cases) and 19 occurred in private schools (191 cases). Of the 17 clusters in traditional public schools, 2 (10 cases) occurred in schools entirely engaged in remote learning.

There were 15 clusters that occurred in the state of North Carolina within traditional public schools providing in-person instruction; 11 of 15 (89 cases) occurred in schools that did not participate in ABCs. One cluster (5 cases of within-school transmission) occurred in an ABCs district that was open for 4 weeks of instruction, and 3 clusters (15 cases of within-school transmission) occurred in the ABCs-participating school districts that provided data for this article. One of these ABCs clusters occurred in a district that exempted mask wearing in prekindergarten during the early days of the school year, a policy that was in accordance with NCDHHS guidance permitting mask exemptions for younger children. As a result of this cluster, the prekindergarten class was closed to in-person instruction temporarily, and the mask wearing exemption in the prekindergarten environment was reversed. Thereafter, there were no additional cases of secondary transmission in the prekindergarten environment in that district.

Two clusters occurred in the special needs environment of ABCs-participating school districts, 1 of which was linked to children eating together in close proximity. In both of these clusters, the district temporarily closed in-person learning at the respective schools. Mask wearing adherence was reemphasized; when mask wearing was not feasible, face shields were employed. Additionally, ABCs and local superintendents jointly developed specialized plans for lunch and breakfast routines to prevent subsequent mealtime transmission. This included eating outdoors when possible, maintaining 6 ft distance, doing all food preparation before taking masks off (eg, opening milk cartons), limiting mask-off time to 15 minutes for eating, and no talking while eating and while masks are off.

Other Lessons Learned

In weekly superintendent meetings, several key contributors to success were noted: daily screening of students and staff, high rates of mask wearing adherence for children and adults, transparency in publicly reporting confirmed SARS-CoV-2 infections (eg, via Web site), efficient contact tracing, close collaboration with local health departments, regular updates with staff and principals to encourage adherence and report secondary transmission cases or any breaches in safety protocols, detailed schedule for all aspects of the school day to adhere to the 3W's, definitive plans for the special needs community, and opening in the hybrid model of instruction. These refinements informed the 12 Principles for Safer Schools.[11]

Superintendents frequently noted operational challenges related to quarantine policies, pandemic fatigue, and family cooperation with contact tracing. The 11 districts reported quarantining >3000 children and staff over 9 weeks. These reductions

TABLE 1 Comparison of School Districts That Were Within and Outside ABCs During the First 9 Weeks of the 2020–2021 Academic School Year in North Carolina

Variables	ABCs Members (*N* = 56)	Other North Carolina Districts (*N* = 59)	Districts Submitting Data (*N* = 11)
Average No. staff	859	540	1172
Average No. students	7739	4516	10 971
Student enrollment by race and ethnicity, %			
Non-Hispanic white	47	55	55
Non-Hispanic Black	27	20	21
American Indian	1	3	<1
Pacific Islander	<1	<1	<1
Asian American	2	1	2
≥2 races	6	6	6
Hispanic[a]	18	15	15
Average No. weeks open for in-person learning in Q1	3.6	5.7	9
No. districts open by week			
Week 1	19	31	11
Week 2	18	30	11
Week 3	18	30	11
Week 4	18	33	11
Week 5	22	36	11
Week 6	23	39	11
Week 7	24	43	11
Week 8	27	46	11
Week 9	31	47	11

Q1, quarter 1 of instruction.

[a] North Carolina reports race and ethnicity in a combined format.

in staff were especially burdensome in smaller districts where employees could not be substituted. As the 9 weeks progressed, 2 districts reported reduced compliance with mask wearing and distancing, primarily within the adult population, so these districts asked ABCs faculty to meet with all of their principals to reinforce the importance of long-term adherence to safety protocols, mask wearing, and distancing at the end of the first instructional quarter.

DISCUSSION

During an ongoing pandemic with widespread community transmission, cases of SARS-CoV-2 with subsequent morbidity and mortality will occur regardless of whether schools allow in-person instruction. A key question exists for policy makers: Is the within-school spread of SAR-CoV-2 greater, equal to, or less than that observed in the broader community? During our study, counties housing the 11 participating school districts had 1–2 new SARS-CoV-2 infections per 1000 residents per week; this is considerable community transmission, as reflected by the 773 community-acquired cases. On average, North Carolina residents with SARS-CoV-2 infected slightly more than 1 other individual during these 9 weeks.[12] If secondary transmission were as common in schools as in the community, we would anticipate up to 900 secondary infections within schools; however, only 32 within-school SARS-CoV-2 transmissions occurred.

SARS-CoV-2 outbreaks and clusters have been commonly reported on residential colleges and universities[1] as well as in overnight camps[2] and an overnight summer school retreat for high school students.[13] SARS-CoV-2 in school-aged children from March 1 to September 19, 2020, peaked in July, in parallel with overall community peaks.[14] Closure of K–12 schools has

TABLE 2 Description of the 11 Districts Within ABCs

District	County Population (No.)	Staff in 2019–2020 (No.)	Students in 2020–2021 (No.)	Hispanic[a] (%)	African American (%)	Asian American (%)	White (%)	Multiple Races[b] (%)	Students in Person 2020 (No.)	Primary Infections (No.)
1	38 755	646	4499	11	4	1	79	5	3972	60
2	28 150	411	2828	13	1	<1	84	2	2163	43
3	43 965	404	5766	16	7	1	72	5	5068	69
4	223 842	3233	29 490	16	23	2	54	5	19 434	315
5	N/A[c]	453	3830	26	20	5	38	10	2835	24
6	184 023	2194	20 038	15	14	3	63	5	16 523	91
7	10 194	171	963	12	34	<1	47	6	628	6
8	102 950	1538	12 376	15	15	1	62	6	8815	69
9	N/A[c]	220	1642	22	8	2	63	5	1024	7
10	181 005	2697	22 971	12	46	2	35	5	12 700	83
11	38 236	664	4963	27	3	<1	66	3	4284	6

N/A, not applicable.

[a] North Carolina reports ethnicity as a separate category within race.

[b] Races with <1% for all districts listed include American Indian and Pacific Islander.

[c] Sites 5 and 9 are city districts, and therefore county population cannot be estimated.

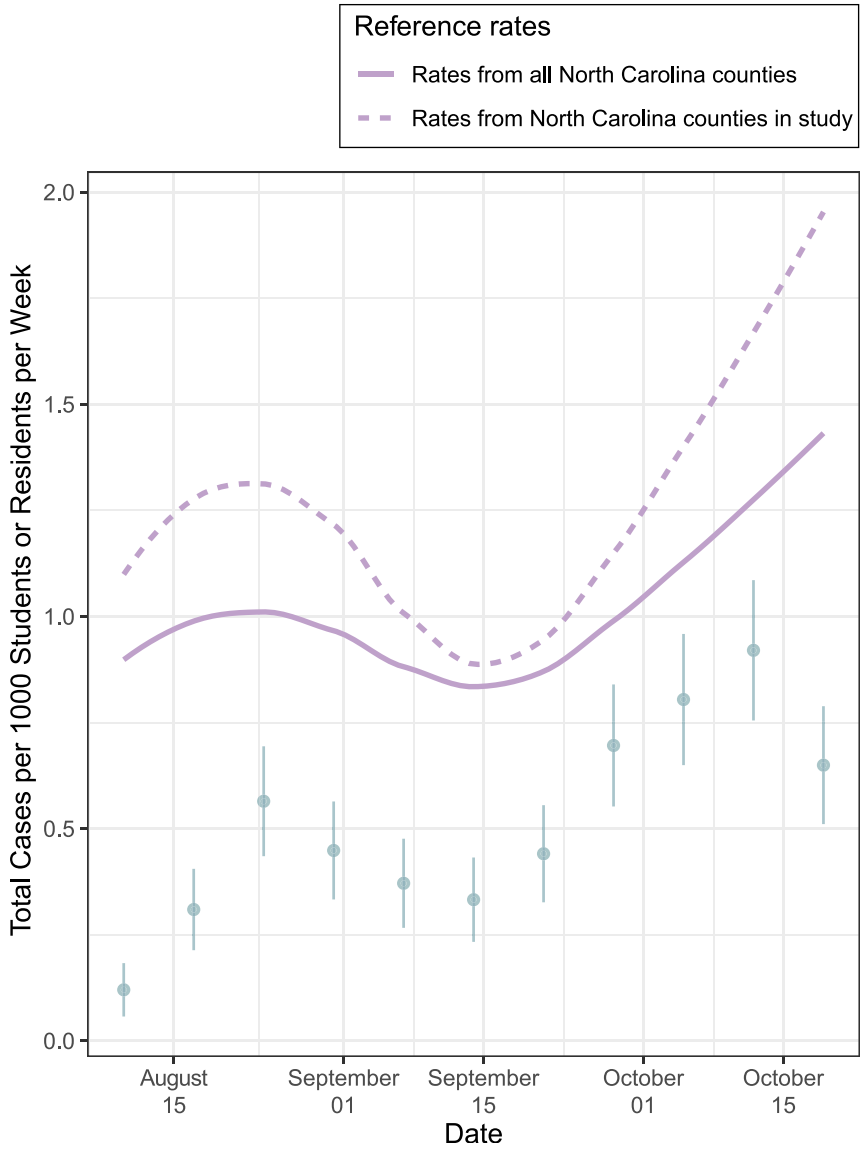

FIGURE 2
Rates of infection: rate of infection across North Carolina (solid line) and in the ABCs 11 districts (dashed line). Dots notate the rates of community-acquired infection within the schools.

often been used as a mitigation strategy for the SARS-CoV-2 pandemic.[15] In a recent systematic review, the authors noted that school closures alone would prevent only 2% to 4% of deaths, which is much less than other social distancing interventions.[16]

Internationally, efforts to minimize school closures in some countries have been implemented with success.[17] Taiwan avoided widespread closures by implementing local temporary school closures based on low thresholds for infected cases within individual schools.[18] Nevertheless, in the United States, few data other than modeling studies are available on SARS-CoV-2 transmission in schools that practiced COVID-19 mitigation strategies, including mask wearing, physical distancing, hand hygiene, and surface disinfection. Our data support the concept that schools can stay open safely in communities with widespread community transmission.

The reasons for district success in limiting secondary transmission were not formally tested; however, common themes emerged during the teleconferences with ABCs faculty and superintendents and are outlined on the ABCs Web site[11] and available for public use. Foremost among these themes was consistent adherence to the 3W's. Additionally, superintendents credited the following important components of success: detailed plans for all activities within school, contact tracing with county health departments, public reporting of infections, and the ability to share lessons learned peer to peer.

North Carolina traditional public schools were especially effective in preventing clusters compared with the private sector. There are ~1.8 million schoolchildren in North Carolina, 80% of whom attend traditional public schools. The remaining 20% attend charter schools or private schools or are homeschooled. Approximately 150 000 children in North Carolina attended private schools (based on attendance from 2019 data) this academic year, but there were more clusters (19) with more SARS-CoV-2 cases (191) in this subgroup than all North Carolina traditional public schools combined.

Most of the cases of secondary transmission in ABCs districts (and all 3 clusters) were related to absent face coverings. These 3 clusters occurred in young children, during lunch, or among children with substantial special needs. In the special needs environment, mask wearing is not always feasible; superintendents reported mask wearing compliance of 50% to 100% for children outside the mainstream classroom because of severe emotional and cognitive disabilities. Of the severely disabled children who cannot wear masks, ~50% are able to wear a face shield. Superintendents also emphasized increased distancing

in the special needs environment, and several ABCs districts implemented tactics related to ventilation (eg, spending more time outside, opening windows when feasible, and improving airflow and filters).

Several policies related to quarantine were especially burdensome for superintendents because of substantial staffing shortages with little gain in public safety. In the 2020 school environment, all individuals within 6 feet of a person infected with SARS-CoV-2 for longer than 15 minutes must self-quarantine, even if all wore masks. This policy is counterproductive for 3 reasons: (1) as evidenced by these data, secondary transmission in the setting of mask wearing is uncommon; (2) this policy discounts the benefits of mask wearing and sends a mixed message to the public on the benefit of face coverings; and (3) in other environments (eg, some health care settings), personnel are not required to quarantine if they have face coverings (even if they were wearing a medical mask rather than an N95 mask) while caring for an asymptomatic patient who has SARS-CoV-2. Moreover, regardless of test results, the 14-day length of quarantine provides little motivation for parents of potentially exposed children to obtain testing, thereby limiting our general understanding of transmission dynamics. Recent guidance from the Centers for Disease Control and Prevention recently provided options to reduce quarantine duration after exposure in the setting of negative testing results[19]; using these updated guidelines to implement mandated testing, with reduced quarantine time after exposure, might address this concern.

Our study has limitations. Participation in ABCs is voluntary, and not every school district in North Carolina participated in ABCs or this study. Participation in ABCs and voluntary submission of data may result in select bias for school districts that enforce adherence to preventive measures, emphasize transparency, and cooperate with peers; these characteristics are likely associated with greater adherence to mask wearing, reduced secondary transmission, and lower risks to students. Adjudication of secondary transmission was by local health department staff in each district, with varying resource capabilities. Although health department staff requested testing of contacts, testing could not be universally enforced because it is not required to return to school in North Carolina. Because of confidentiality concerns, we were not able to analyze incidence of child-to-child or adult-to-child transmission, nor could we determine the relative effectiveness of any specific school policies. Finally, these data are applicable to reduced population density, both through the hybrid model and from students within the districts (approximately one-third of students) opting to remain remote.

CONCLUSIONS

Our cohort study revealed that enforcing SARS-CoV-2 mitigation policies, such as mask wearing, physical distancing, and hand hygiene, resulted in minimal clusters of SARS-CoV-2 infection and low rates of secondary transmission in schools and did not cause a larger community infection burden. Our data indicate that schools can reopen safely if they develop and adhere to specific SARS-CoV-2 prevention policies.

ACKNOWLEDGMENTS

We thank the following people for their contributions and dedication to ABCs: Susan Landis, project management, Duke Clinical Research Institute, Duke University School of Medicine; Jennifer Hefner, superintendent, Alexander County Schools; Eisa Cox, superintendent, Ashe County Schools; Jeff Wallace, superintendent, David County Schools; Jeff Booker, superintendent, Gaston County Schools; Robbie Adell, superintendent, Hickory Public Schools; Jeff James, superintendent, Iredell-Statesville Schools; Ben Thigpen, superintendent, Jones County Public Schools; Robert Grimesey, superintendent, Moore County Schools; Kim Morrison, superintendent, Mount Airy City Schools; Ethan Lenker, superintendent, Pitt County Schools; Todd Martin, superintendent, Yadkin County Schools; Boen Nutting, Iredell-Statesville Schools; Lori Dingler, lead registered nurse, Davie County; Seth Powers, Moore County Schools; Betty Worthy, Gaston County Schools; Jed Cockrell, Yadkin County Schools; Kristi Gaddis, Yadkin County Schools; Penny Willard, Mount Airy City Schools; Robin Helton, Alexander County Schools; Danielle Bryan, Jones County Public Schools; Angela Simmons, Hickory Public Schools; and Karen Harrington, Pitt County Schools.

ABBREVIATIONS

3W's: wear a mask, wait 6 ft, wash hands
ABCs: The ABC Science Collaborative
COVID-19: coronavirus disease 2019
K–12: prekindergarten through grade 12
NCDHHS: North Carolina Department of Health and Human Services
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded by the Trial Innovation Network (sponsored by the National Institutes of Health's National Center for Advancing Translational Sciences [5U25TR001608-05]), which is an innovative collaboration addressing critical roadblocks in clinical research and accelerating the translation of novel interventions into life-saving therapies. Also funded by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (contract HHSN-275201000003I) for the Pediatric Trials Network (Principal Investigator Dr Benjamin). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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